

Homework Report: 1D Wave Equation

Summary

The goal is to implement a 1D wave equation, conduct a timing study of it, and analyze the performance of the simulation. It models wave propagation using spatial and temporal grids and includes different conditions and constraints.

Implementation

The language used to implement the equation is Python 3.10 and the required libraries are NumPy and Matplotlib. Here is how to make sure you have everything ready:

1. Install Python 3.10 or later
 - a. To do this go to the python website and download one of the necessary versions
2. Install the required libraries using pip in your terminal
 - a. `pip install numpy matplotlib`

After doing this you will then need to use the python scripts and file to run the simulation. To do this “cd” into the proper directory and then activate the script. This is done by entering the following command into your terminal:

```
python wave_sim.py
```

This command should execute the python file and code in it as well as generate an output in your terminal.

Timing Results

The timing study revealed the following average runtimes (over 5 repetitions):

Number of Timesteps	Average Runtime (seconds)
10	0.0006
100	0.0018
1,000	0.0076
10,000	0.07774
100,000	0.7920
1,000,000	8.3272
Average	1.53449

The execution time scales linearly with the number of timesteps, demonstrating the expected behavior for this implementation. These were all run using a Windows 11 CPU, with RAM 16 GB DDR4.

Optimization

There are several ways to improve the performance of the simulation which include:

1. Parallelization
 - a. Use the multiprocessing or parallel libraries to exploit multiple CPU cores
2. Memory Optimization
 - a. Use in-place updates for position and velocity arrays to reduce memory
3. Compiled Languages
 - a. Implement the simulation in a compiled language like C++

All of these are some of many suggestions as to how I could improve the efficiency and speed of the simulation.

